Contents

4 **On the Road to Future Fuels** FETC's fuels programs propel us toward a cleaner environment.

9 **Hydrates—The Final Natural Gas Frontier** Methane hydrates could be the answer to the world's fossil energy needs.

10 **Where's the Gas? Natural Gas, That Is** Two approaches ensure a continued supply of natural gas: researching new and better ways of recovering gas, and finding new sources of gas.

16 **To Market, to Market** Advances in gas-to-liquids technology may allow for economic transportation of stranded natural gas and give the trans-Alaska pipeline a second life.

20 **Fuel for the New Millennium** High efficiency diesel, diesel/battery hybrids, and fuel-cell powered engines are being developed, but where will we get the fuel to make them go?

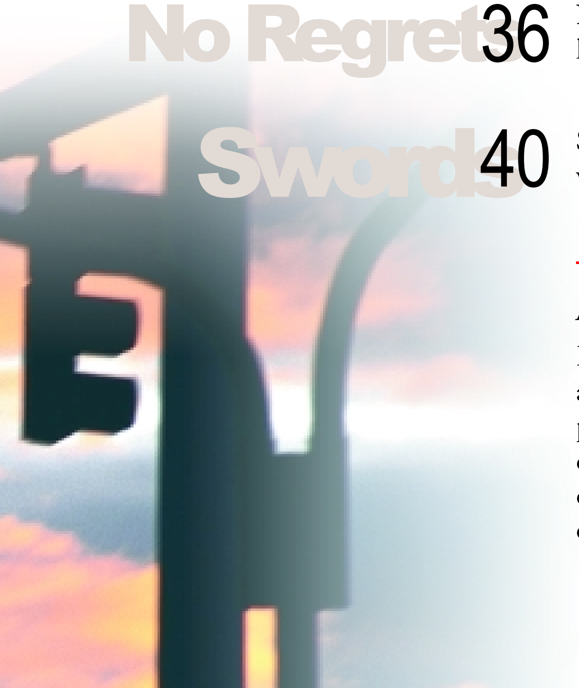
26 **Alternatives to Gasoline—Today** No need to wait! Alternative-fuel vehicles and alternative-fuel stations are available right now.

30 **Drink Your Car Exhaust?** In the quest for a clean, sustainable, domestic energy supply, hydrogen could be the best option.

35 **Fossil Fuels—How They Were Formed** One million years from now, the Everglades could be a large coal bed.

36 **No Regrets-Kutlwanong** Research in low-smoke fuels and energy-efficient homes is making a difference in addressing South African health concerns.

40 **Swords to Plowshares** What is our strategy for the disposition of weapons-grade plutonium in a safe, effective way?



About the Cover:

Family vehicles in the U.S. consume enough fuel each year to cover a regulation-size football field to a depth of about 40 miles. FETC partners with industry and other organizations to develop and deploy ultra-clean, high-performance fuels, ensuring that we can continue to depend on our transportation-based economy to bolster our transportation-based lifestyle.

Venkat K. Venkataraman
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To Market to Market...

A new take on an old technology may extend the life of the trans-Alaska pipeline, enable production of more North Slope oil, and put Prudhoe Bay's vast natural gas resources within our reach.

Stretching 800 miles across Alaska—from Prudhoe Bay on the Arctic Ocean, to Valdez on the Gulf of Alaska—the trans-Alaska pipeline has carried almost 13 billion barrels of crude oil to market since it was completed in 1977. Even with oil production in Prudhoe Bay now dwindling from its 1988 peak, the pipeline still transports over 20 percent of the crude oil produced in the United States. The pipeline, which snakes across three major mountain ranges and hundreds of rivers and streams, has been described as a "giant straw" through which the United States sucks up to 1,000 gallons or 24 barrels of oil a second. When it shuts down, as it will when production drops below the 200,000 barrels needed each day to keep the pipeline in operation, the impact on Alaska's economy will be significant. Some projections show this happening in less than 10 years.

What may extend the life of the trans-Alaska pipeline is another fossil fuel found in abundance in Alaska's North Slope: natural gas. This resource has remained untapped because it has been too remote to be produced and transported profitably. Marooned pockets of gas like this, which can't be economically brought to market, are called "stranded"—and the North Slope isn't the only place they exist. It is estimated that the United States has about 275 trillion cubic feet of stranded gas in remote locations, primarily in Alaska and beneath the deep waters of the Gulf of Mexico. Recent advances in a technology called gas-to-liquids, or GTL, may bring this remote gas into economic reach by lowering production and transportation costs. If GTL is used to move the North Slope's gas, this could add at least a quarter of a century to the pipeline's life.

Venkat Venkataraman visited the trans-Alaska pipeline when he chaired a day-long public review meeting of DOE's gas-to-liquids program in Anchorage, Alaska, in May 1999. Held during the Society of Petroleum Engineers Western Regional Meeting, the meeting brought public- and private-sector professionals together to share progress and results, and to discuss the status of DOE-funded research.

Everything Old is New Again

The heart of GTL technology is an old process making a comeback: the Fischer-Tropsch (F-T) process. Developed by the German chemists Franz Fischer and Hans Tropsch in 1923, the process converts natural gas into a clean, easily transported, petroleum-like liquid that can be refined to create fuels and other products. Although the process has been around for a long time, it hasn't found wide application because it has been prohibitively expensive. Only in a few cases, when countries were cut off from the world oil market, has it made economic sense to produce liquid fuels this way: Germany used F-T technology during World War II to make gasoline from coal-derived gas, for example, and South Africa started using it during the apartheid era.

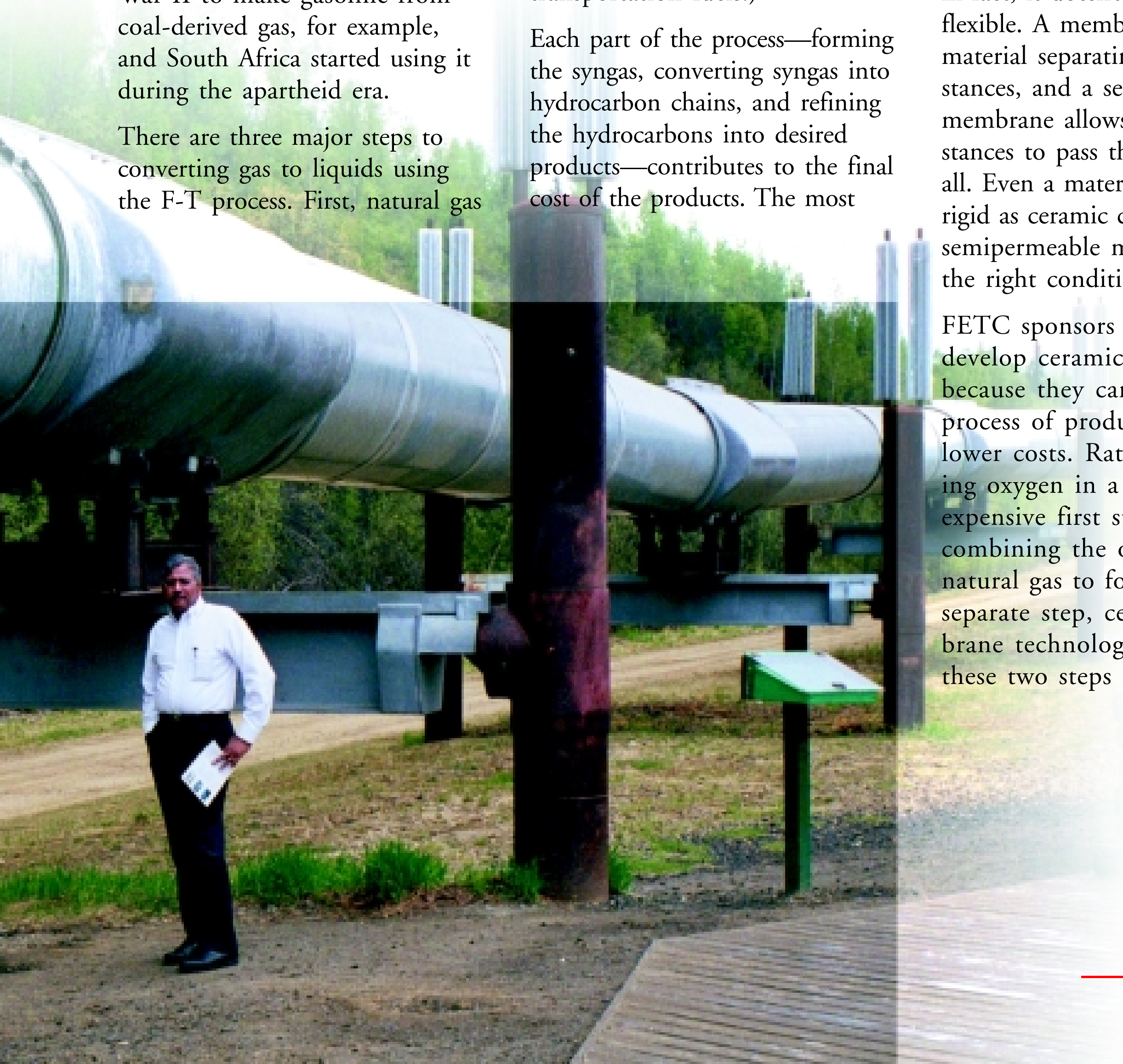
There are three major steps to converting gas to liquids using the F-T process. First, natural gas reacts with oxygen to form a mixture of hydrogen and carbon monoxide called synthesis gas, or syngas. In the next step, the F-T synthesis, high temperatures break the chemical bonds in the gas molecules, and a catalyst rearranges the hydrogen and carbon into chains called hydrocarbons. The hydrocarbon chains—which vary in length from the short- and medium-length chains found in gasoline and kerosene to long-chain waxes—can then be refined to create liquid fuels, such as gasoline and diesel, and other products, like candle wax. (See "Fuel for the New Millenium" on page 20 to learn how F-T liquids can be used for zero-sulfur transportation fuels.)

Each part of the process—forming the syngas, converting syngas into hydrocarbon chains, and refining the hydrocarbons into desired products—contributes to the final cost of the products. The most expensive step, accounting for about two-thirds of the total cost, is producing the syngas. Reducing the cost of this step, through research in promising technologies like ceramic membranes, is one of the main thrusts of FETC's GTL research.

Ceramic Membranes

When you think of membranes, you may think first of the biological definition: a thin, pliable sheet or layer of tissue—like a cell membrane, or your ear drum, the tympanic membrane. Thinking further, you might remember your high-school biology lab on osmosis, and you'll recall that a membrane doesn't need to be made of tissue; in fact, it doesn't even need to be flexible. A membrane is simply a material separating two substances, and a semipermeable membrane allows some substances to pass through, but not all. Even a material as dense and rigid as ceramic can act like a semipermeable membrane under the right conditions.

FETC sponsors research to develop ceramic membranes because they can simplify the process of producing syngas and lower costs. Rather than purifying oxygen in a relatively expensive first step, and then combining the oxygen and natural gas to form syngas in a separate step, ceramic membrane technology combines these two steps into one.



The process works by passing air along one side of a ceramic membrane and natural gas, which is mostly methane, along the other. Although ceramic is generally impermeable, there are “vacancies” in its molecular structure—not really pores, but rather, unoccupied slots that charged particles can fill. At temperatures above about 700°C, these vacancies become mobile, allowing oxygen in the air to move across the membrane by “hopping” from one vacancy to another. When the oxygen, which is mostly in the form of oxide ions (O^{2-}), reaches the surface on the natural-gas side of the membrane, it reacts with the methane in the natural gas to form syngas.

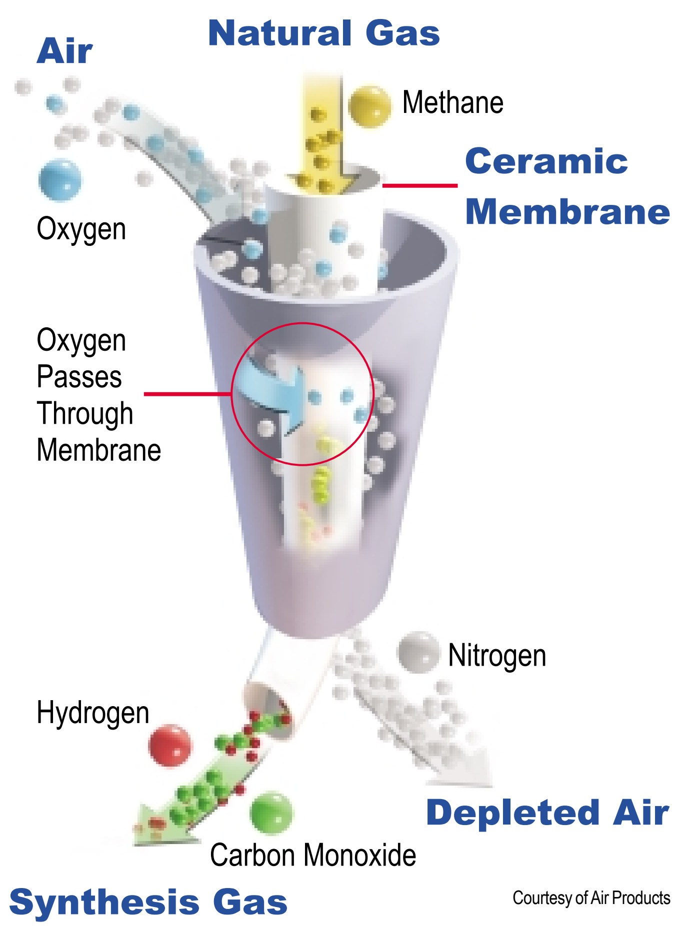
The actual shape of ceramic membranes depends on the application, but they can be pictured as being round, like pipes or tubes. In the one-step syngas process, clusters of membranes are contained within a reaction vessel—an arrangement engineers call a “shell and tube” configuration. Methane flows through the inside of the tube-like membranes, and air flows outside the membranes, but inside the vessel. The net effect is that methane flows in one end of the membranes, and syngas flows out the other.

FETC is working with two different research teams to develop ceramic membrane technology for syngas production. One effort, led by Air Products and Chemicals, Inc., of Allentown, Pennsylvania, is an 8-year, $86 million project that will be done in three phases, with FETC funding about 35 percent of the total cost. Other partners include ARCO; Ceramatec, Inc.; Chevron; Eltron Research, Inc.; McDermott Technology, Inc.; Norsk Hydro; Pacific Northwest National Laboratory; Pennsylvania State University; and the University of Pennsylvania. In a smaller project, the University of Alaska Fairbanks is leading a team that also includes BP Amoco, the University of Illinois at Chicago, the University of Missouri-Rolla, the University of Houston, and the Massachusetts Institute of Technology.

An Eye on the Bottom Line

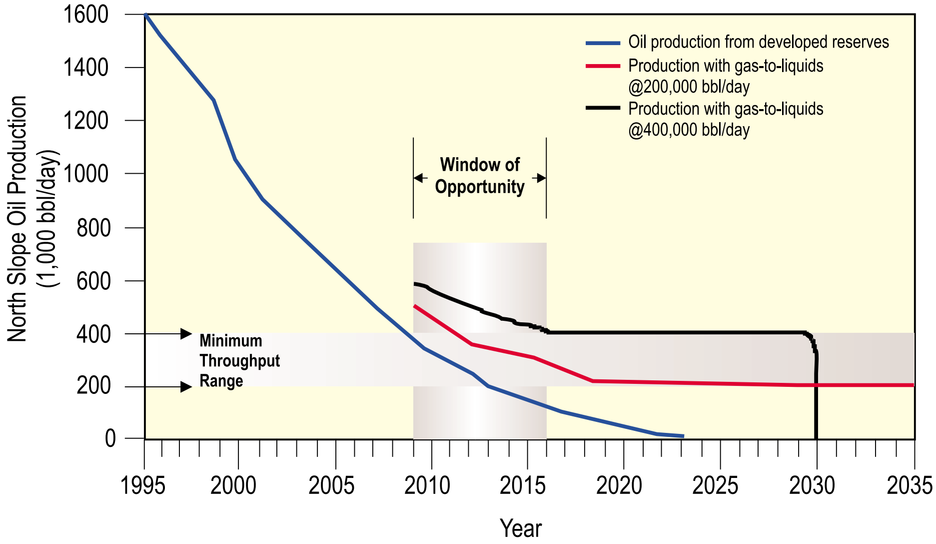
The potential is great . . . the technology is exciting . . . but is GTL the only way to bring the North Slope’s gas to market? And if it’s not the only way, is it the best way? To answer these questions, you need to bear in mind that right now there’s no way to bring this gas to market, or at least no economic way. Determining how to produce and transport this gas requires economic analysis, and reanalysis as new technologies change the economics of different options.

In 1996, the Idaho National Engineering and Environmental Laboratory (INEEL) conducted a FETC-supported economic assessment to compare options for producing natural gas from Alaska’s North Slope. Their report, *Economics of Alaska North Slope Gas Utilization Options*, was expanded this year with a follow-up investigation and report,



Courtesy of Air Products

Alaska's Window of Opportunity



Options for Gas-to-Liquids Technology in Alaska. Both assessments compared GTL with liquefied natural gas (LNG) technology, which converts natural gas to liquid by cooling it to very low temperatures.

Unlike GTL, the LNG scenario would require construction of a new 800-mile pipeline to transport natural gas from the North Slope. The gas would be converted to LNG at a new plant that would be constructed at or near Valdez, and the LNG would be shipped by specialized LNG tankers for end use.

In the GTL scenario, a GTL plant would be constructed on the North slope, and GTL-derived liquid would be transported through the existing pipeline to Valdez where it would be shipped by crude-oil tankers.

The GTL option offers several advantages over LNG, the most obvious being that it would not require a new 800-mile pipeline. Constructing a new pipeline would be an enormous capital expense—approximately $14 billion—and it would risk putting Alaska through another boom-and-bust cycle, like the one triggered when the trans-Alaska pipeline was constructed during the 1970s. Transporting GTL-derived liquids through the existing pipeline would also make more of the North Slope's oil producible. By combining GTL-derived liquids and crude oil in the pipeline, crude could be transported, even when its production falls below the minimum amount otherwise needed to keep the pipeline in operation. Extending the life of the pipeline would also reduce per-barrel pipeline fees by spreading operating costs over more barrels of oil or GTL product.

As good as this all sounds, the best way to produce and transport the North Slope's gas will be decided, in large part, by the bottom line, which is where the INEEL assessments come in. Although both assessments compared the same technologies, changed market conditions and advances in GTL technology between 1996 and 1999 produced different results. The initial report concluded that the economics of LNG were slightly more favorable; in this year's follow-up, GTL was found to have the edge. More economic analysis will be needed before it is decided how the North Slope's gas will be brought to market—including assessments by the multiple companies that control the gas and the transportation network. But the INEEL reports clearly show how recent innovations are enhancing the economics of GTL technology, making it an increasingly attractive option—quite possibly the better one.

Whatever the outcome on the North Slope, FETC and its research partners will continue work to improve the GTL process. Other pockets of stranded gas could benefit from GTL technology, and continued research and innovation will ensure that the process is as efficient and cost-effective as it can possibly be. GTL technology, with its early-20th century roots, could be the 21st century solution that brings stranded gas to market.

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